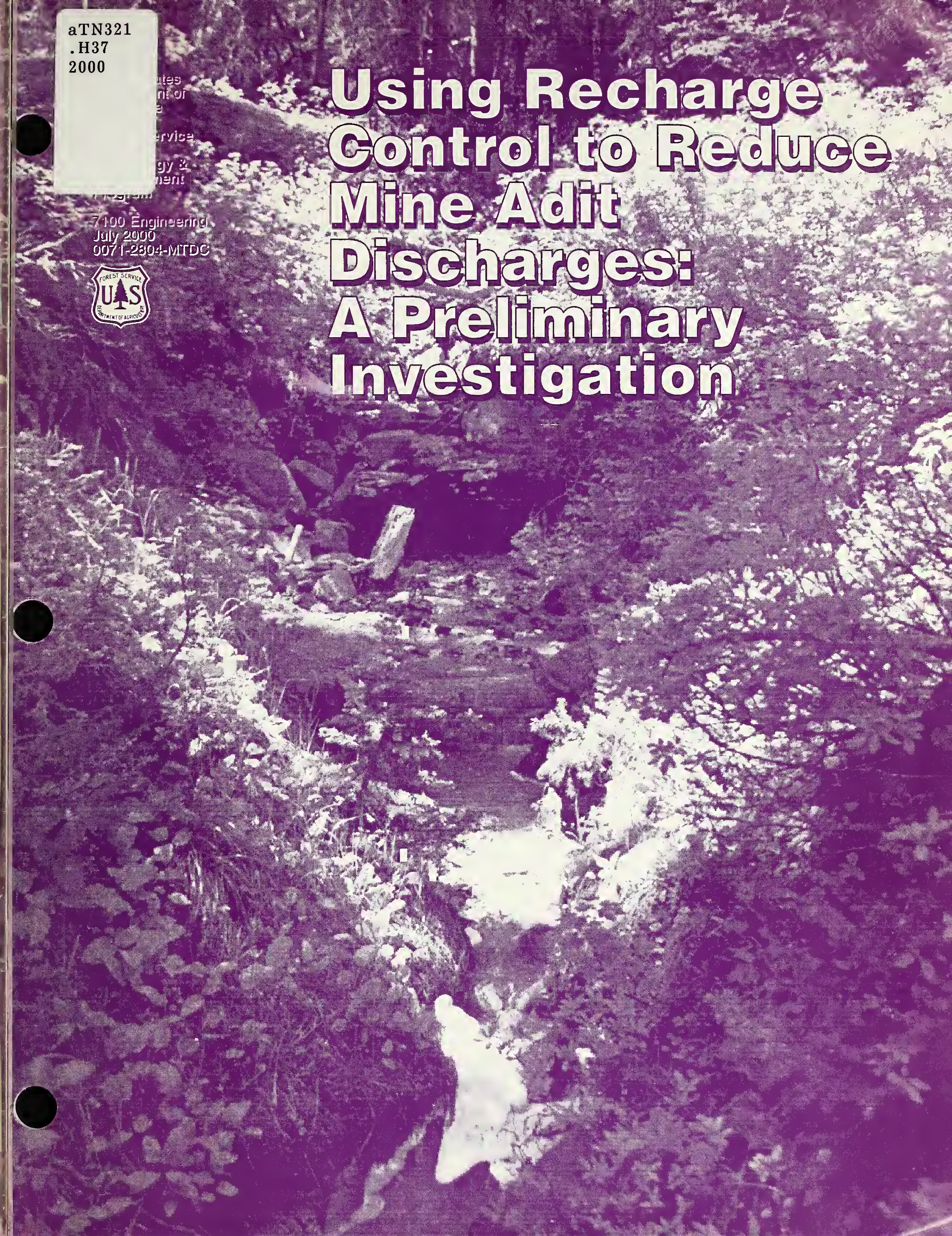
...tes
...nt of
...e

...ervice

...gy &
...nent

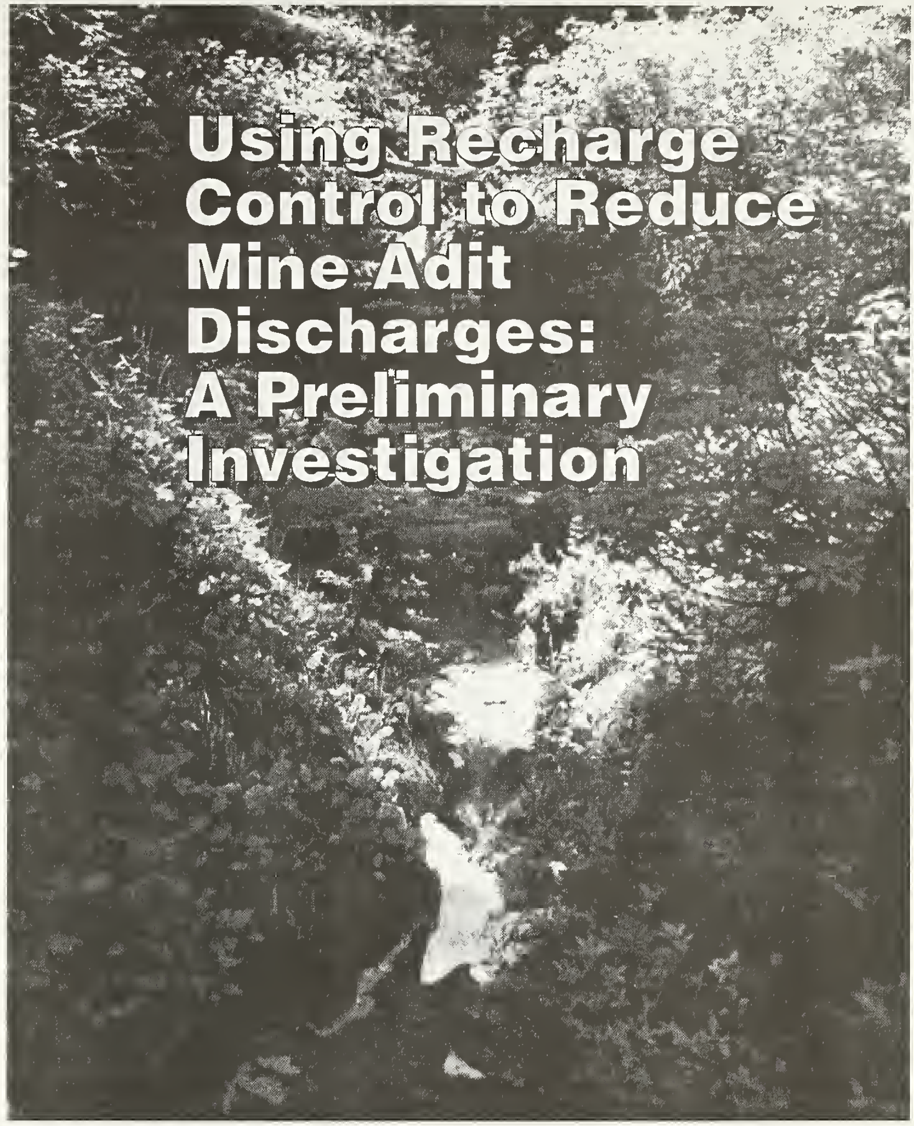
7100 Engineering
July 2000
0071-2804-MTDC

Using Recharge Control to Reduce Mine Adit Discharges: A Preliminary Investigation



United States
Department of
Agriculture

National Agricultural Library



Using Recharge Control to Reduce Mine Adit Discharges: A Preliminary Investigation

Phyllis A. Hargrave
Geologist

John J. Metesh
Hydrogeologist

Steve Oravetz
Program Leader

USDA Forest Service
Technology and Development Program
Missoula, Montana

0E02G50—Contaminated Ground Water

July 2000

Table of Contents

Introduction

Acid mine drainage (AMD) from abandoned mines contributes to the degradation of streams and riparian areas and may harm fish and wildlife. Plugging mine openings to eliminate or reduce the flow of AMD has only had limited success. Expensive water treatment plants that require power and frequent maintenance are not feasible for abandoned mine sites on remote lands managed by the Forest Service. The Missoula Technology and Development Center (MTDC) has been asked to investigate passive AMD treatments that may work on small, remote abandoned mine sites typical of National Forests.

MTDC and the Montana Bureau of Mines and Geology entered into a participating agreement to produce two reports dealing with AMD. The first report (*Treating Acid Mine Drainage From Abandoned Mines in Remote Areas*, 9871-2821-MTDC, 1998) summarized literature about the different types of passive treatment methods that offer the greatest chance of success for remote, inactive mines that produce flows of less than 20 gallons per minute (gal/min). This report discusses most of the Montana AMD sites with adit discharges that have potential for passive treatment. The information gathered about the mines provides a good basis to identify sites in Montana for the application of recharge control, a passive treatment method discussed in our first report. The Vindicator and Beatrice Mines in Montana are discussed in detail. These mines are considered good candidates for reducing or preventing AMD using recharge control.

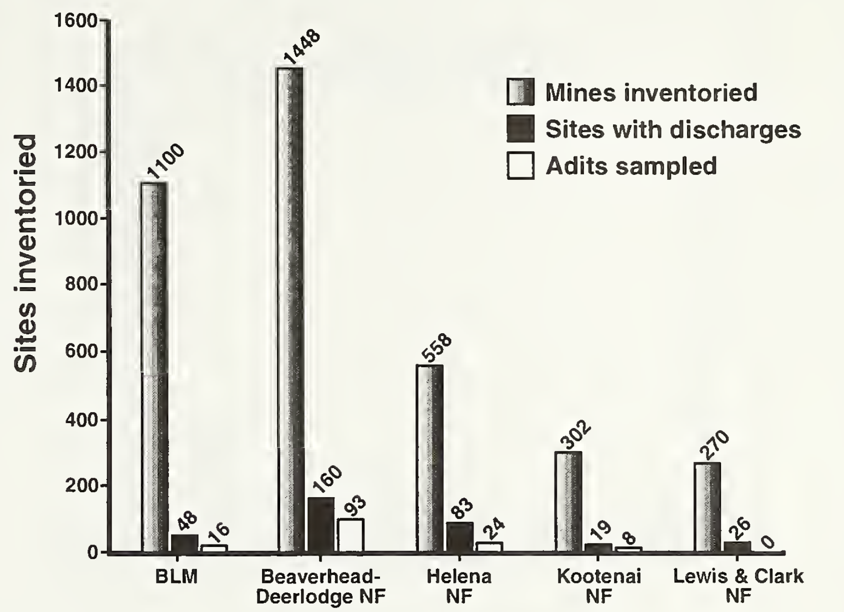


Figure 1—More than 3,000 mine sites were inventoried on National Forests and Bureau of Land Management Resource Areas in Montana. Of these, 336 sites had one or more adits discharging water at least part of the year. A total of 141 adit discharges were sampled.

The Montana Bureau of Mines and Geology (MBMG) lists 8,120 sites in its abandoned and inactive mines data base. The MBMG has inventoried and collected information for 3,678 of these sites on lands administered by the USDA Forest Service and USDI Bureau of Land Management (Figure 1). In a program developed by the Bureau of Mines and the Forest Service, the location of each site is verified and compared to a set of screening criteria that determines the action taken at each site. In general, the sites are investigated on a watershed-by-watershed basis within each National Forest or BLM Resource Area. Inventories and preliminary evaluations have been completed for the Beaverhead-Deerlodge, Helena, Kootenai, and Lewis and Clark National Forests and for BLM-administered lands Statewide. Sites in the Lewis and Clark National Forest were not sampled because all of the discharging adits inventoried to date are on private land. All the information collected is stored in the MBMG Abandoned and Inactive Mines data base and Groundwater Information Center data base. The site evaluations for each drainage are summarized in a series of reports by the Montana Bureau of Mines and Geology.

While identifying mines and mills associated with National Forests and BLM Resource Areas, the MBMG identified 336 sites where one or more adits were discharging water at least part of the year. Of these sites, 127 were on Federal land. Fourteen of these sites had more than one discharging adit. A total of 141 adit discharges were sampled. Many other adits on private land may have an effect on National Forest lands. Those adits were not directly sampled. Their effects were measured by sampling on Federal lands upstream and downstream of the private site where appropriate. Other adits were classified as having discharges but were not sampled because they were not flowing at the time of sampling due to seasonal variations.

The majority of the adits (78 percent) discharge water at rates of less than 10 gal/min (Figure 2). Only six adits had discharges over 100 gal/min. The primary factor in controlling the rate of discharge is the relative depth and extent of the underground workings. Mines with extensive horizontal workings or with adits on the lower slopes of a watershed have larger

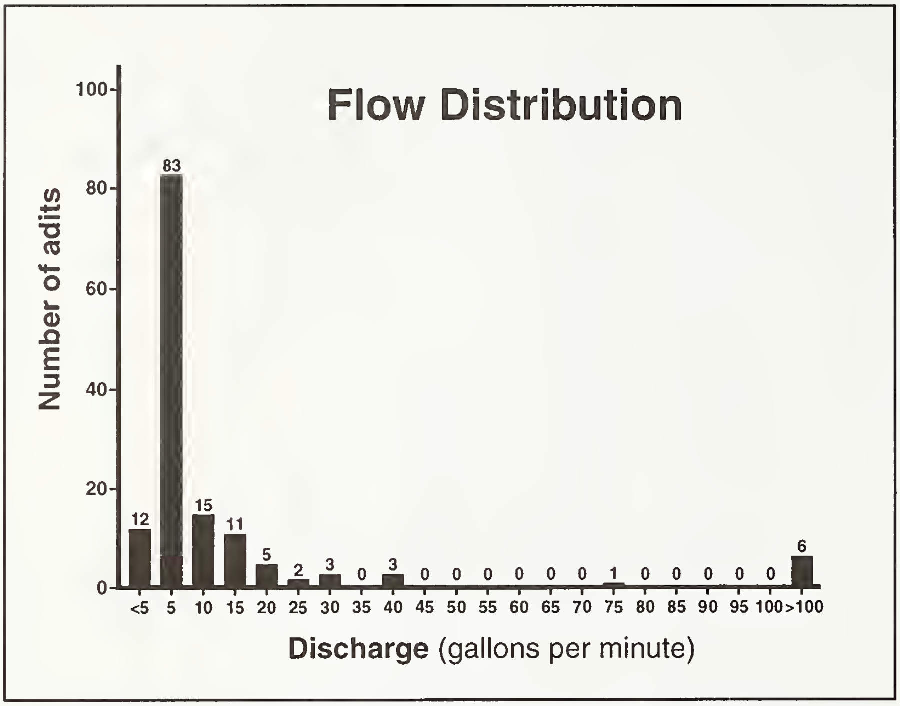


Figure 2—Of the 141 adit discharges sampled, only six were discharging more than 100 gallons per minute. Most discharges were from 5 to 10 gallons per minute.

capture zones to intercept ground water. The same is true for the horizontal extent of the workings. Sites with adit discharges greater than 50 gal/min generally have at least 1,500 feet of vertical and horizontal workings.

Water-Quality Standards

The Safe Drinking Water Act directs the Environmental Protection Agency (EPA) to develop standards for potable water. Some of these standards are mandatory (primary), and some are desired (secondary). The standards established under the Act are often referred to as primary and secondary maximum contaminant levels (MCL's). Similarly, the Clean Water Act directs the EPA to develop water-quality standards (acute and chronic) that will protect aquatic organisms. The primary and secondary MCL's and the acute and chronic Aquatic Life Standards for selected metals are listed in Table 1.

Sixty-three of the 141 adit discharges exceeded one or more of the six water-quality criteria (Figure 3). The adits with the higher discharge rates generally had better water quality, but overall, there was no apparent correlation between water quality and discharge rate. As would be expected, there is a strong correlation between water quality and the ore deposit and the mineralogy of the country rock. For the sites studied, there did not appear to be a relationship between water quality and the condition of the adit (open or closed).

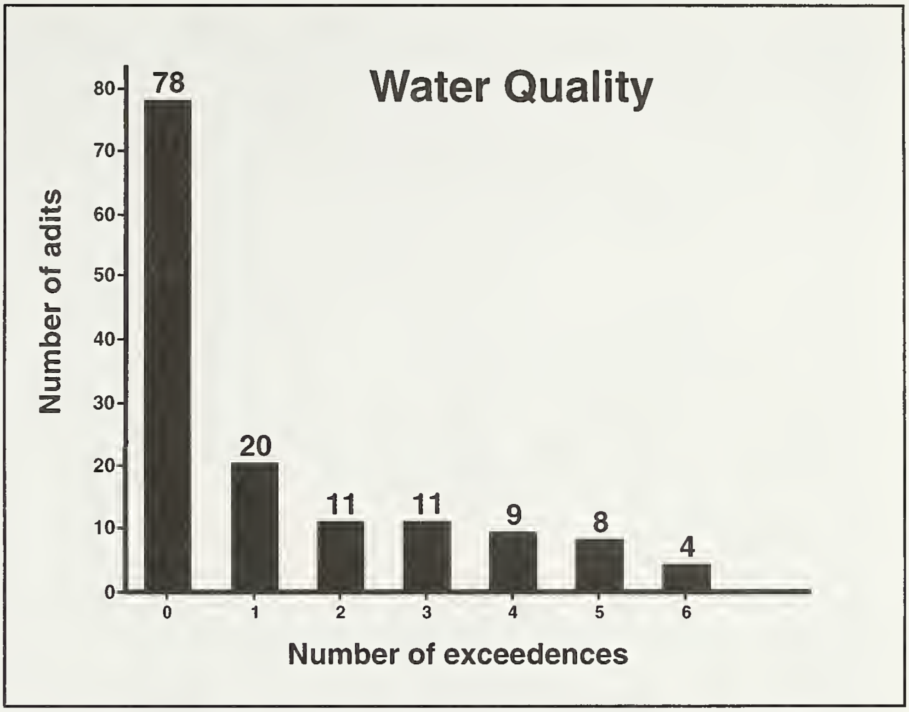


Figure 3—Discharges from 141 adits at inactive or abandoned mines in Montana were sampled. Water quality was within Environmental Protection Agency water quality limits for six standards at 78 adits. Water quality at four adits exceeded all six standards.

Table 1—Partial list of Environmental Protection Agency water-quality standards. The acronym MCL stands for maximum contaminant level.

	Primary MCL(1) (µg/L)	Secondary MCL(2) (µg/L)	Aquatic Life Acute(3,4) (µg/L)	Aquatic Life Chronic(3,5) (µg/L)
Arsenic	50	—	360	190
Cadmium	5	—	3.9/08.6(6)	1.1/2(6)
Copper	—	1000	18/34(6)	12/21(6)
Lead	50	—	82/200(6)	3.2/7.7(6)
Zinc	—	5000	120/210(6)	110/190(6)
pH (Standard Units)		6.5-8.5		

(1) 40 CFR 141; revised through 8/3/93.
(2) 40 CFR 143; revised through 7/1/91.
(3) Priority pollutants, EPA Region VIII, August 1990.
(4) Maximum concentration not to be exceeded more than once every 3 years.
(5) 4-day average not to be exceeded more than once every 3 years.
(6) Hardness dependent. The first value is calculated at a hardness of 100 mg/L; the second is calculated at 200 mg/L.

The impacts of abandoned and inactive mines (Figure 4) can be classified using several factors, such as individual metals being contributed by the discharge, the acidity of the water, and the total flow. The rock type with which the deposit is associated may be used to predict water chemistry to a limited extent. The cumulative effect of several mines to the waters of an individual drainage should also be examined. The screening and sampling system used by the MBMG Abandoned and Inactive Mines Program is based on individual factors that may be used in any combination to rank mine sites according to the needs of the investigator. The total effect or total daily load of dissolved contaminants should be compared using several factors. In addition to adit

Figure 4—Although vegetation in the riparian area is healthy downstream from the Vindicator Mine in southwestern Montana, pore spaces in the stream substrate are filled with iron-oxide precipitate from acid mine drainage.

discharges and flooded shafts, other factors include tailings or waste in the flood plain, seeps at the base of waste dumps, and springs associated with the site. These factors are not discussed in this report but should be considered in a site's overall assessment.

Direct treatment of adit discharges poses many limitations. Most sites are remote and without power. Year-round access may be limited. Any treatment design must be passive. Similarly, most adits have only a small area, often formed by waste rock, to serve as a staging area when setting up a treatment facility. Reclamation by removing or regrading waste rock (Figure 5) near the adit further limits the area available for passive treatment systems (discussed in *Treating Acid Mine Drainage From Abandoned Mines in Remote Areas*, 9871-2821-MTDC). The wetlands approach to treatment generally requires about 60 square feet of wetland for each gallon per minute of treated water, depending on the concentration of dissolved metals. An adit discharging 10 gal/min, would need 600 square feet of wetlands for treatment, more area than is available for treating most adit discharges. Direct control of adit discharge by plugging, grouting, or recharge control may require temporarily disturbing the portal area, but probably offers the best long-term solution to most adit discharge problems.

Controls on the rate and quality of the adit discharge are a function of the mineralogy, geology, and hydrogeology of the rock affected by the mine. Each of these three factors controls the quality, direction, and quantity of ground water flowing into and around the workings. The most common approach to eliminating discharge from an adit is to construct an adit plug. This option has proven to be expensive and, in several cases, has resulted in catastrophic failure. The adit discharge can be

Figure 5—Waste rock was dumped in the stream channel at the Beatrice Mine site near Helena, MT. The stream channel now contains large amounts of iron hydroxide, called Yellow Boy by the miners, that is precipitated by acid mine drainage.

reduced or eliminated in many cases by reducing groundwater flow into the workings. Backfilling and recontouring mine-related excavation, mechanically reducing soil permeability, and diverting storm water and snowmelt can significantly reduce the infiltration of water into the workings. Detailed information of the extent of workings, the mineralogy, and production history of a mine is needed, but is often not available. Field reconnaissance and literature pertaining to the general area can be used to identify sites that may be good candidates for reducing or eliminating adit discharge by reducing groundwater flow into the workings.

Of the 63 adits discharging water that exceeds one or more water-quality criteria, about 47 would be good candidates for recharge control. Small open pits and cat-cuts uphill and above the workings act as catchment basins for snowmelt and storm-water runoff. Adits that are good candidates for recharge control are generally near the drainage divide. The effective recharge area for groundwater entering the mine is probably limited to a few thousand square feet. The remaining sites would probably require a combination of recharge control, grouting, and adit plugging. In some cases, only a reduction in flow could be expected, but that reduction may allow end-of-pipe treatment methods to be used.

Vindicator Mine

The Vindicator Mine (Figure 6) is in a small tributary to the upper portion of Basin Creek in the Beaverhead-Deerlodge National Forest (Township 7 North, Range 6 West, Section 12). The site (Figure 7) was inventoried and sampled in June 1992 and summarized in a report on the Basin Creek drainage (Metesh and others 1994).

The mine exploited near-surface veins contained within three parallel shear zones that were an average of 5 feet wide. Gold and silver were the target ores, but quartz, calcite, pyrite, galena, sphalerite, tetrahedrite, chalcopyrite, and tourmaline are present in the veins. The total production of the mine, which operated from 1936 to 1940, was about 92 tons. The total extent of workings is less than 1,000 feet. No maps are available for the underground workings.

Figure 7—The sides of this manmade channel at the Vindicator Mine in southwestern Montana are prone to collapse, adding sediment to the stream.

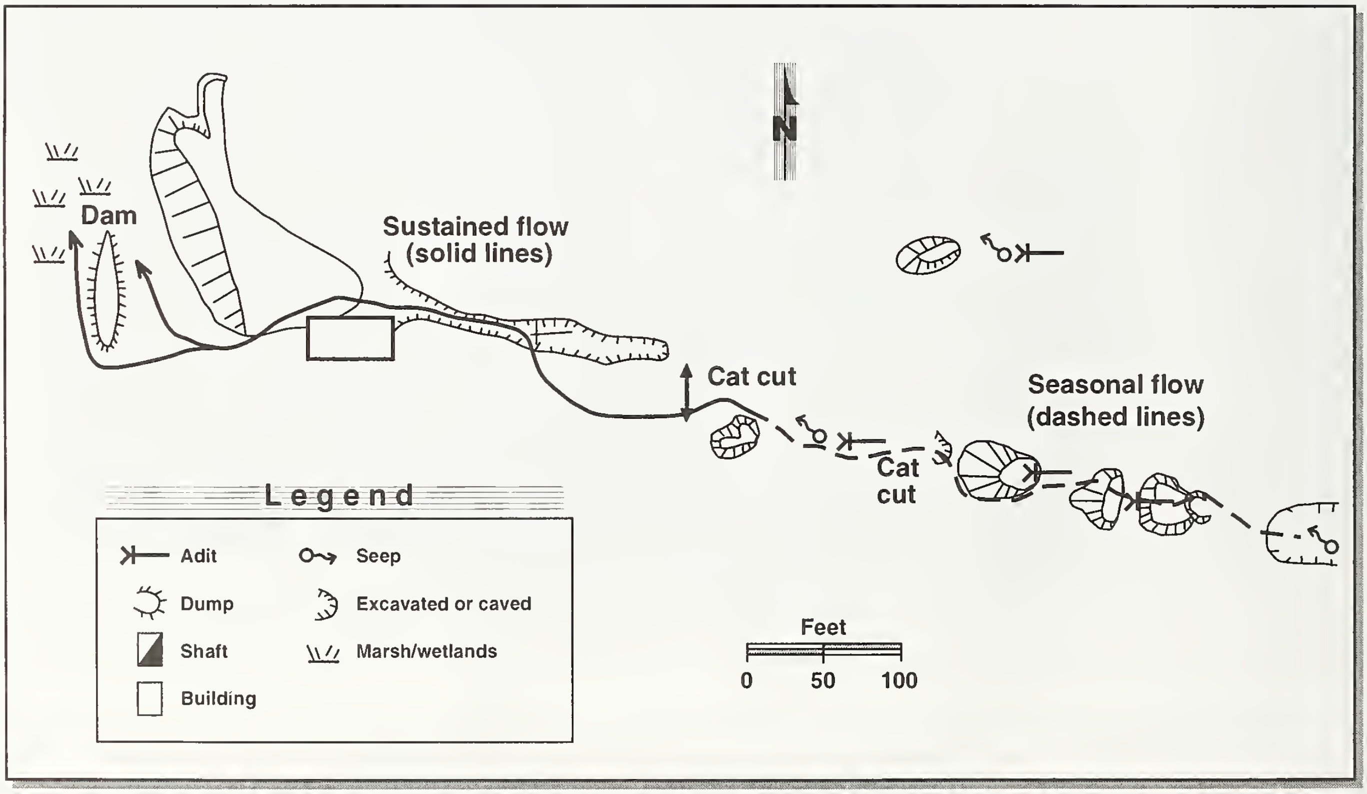


Figure 6—The workings of the Vindicator Mine in southwestern Montana are shallow and lie within a narrow shear zone. The seeps and adit discharges are fed by surface water flowing into the drainage.

Based on the location of the adits and associated waste-rock dumps, few or none of the workings are perpendicular to the shear zone. The workings are probably shallow and restricted to a narrow zone coincident with the natural drainage.

Discharge from adits (Figure 8) and seeps ranged from less than 0.5 gallons per minute at the upper part of the site to about 12 gallons per minute at the lowest adit. Staining and vegetation at the site indicate that the rate of discharge from the springs and adits varies seasonally. The water from the site was generally poor quality. Although the pH was nearly neutral, drinking water criteria and aquatic life criteria were exceeded for dissolved cadmium, copper, lead, aluminum, and zinc at two of the larger seeps.

Figure 8—A closed adit at the Vindicator Mine.

Adit discharges at the Vindicator Mine could be reduced or eliminated by reducing the recharge to the workings. With shallow workings restricted to a narrow zone within the bottom of the ephemeral drainage, the recharge to the workings is probably dominated by water infiltrating from surface runoff. Surface application of low permeability material over the top of the regraded waste-rock dumps and excavations would reduce the infiltration of water into the workings. The result should be reduced or eliminated flow from the adits and seeps associated with the mine.

Beatrice Mine

The Beatrice Mine (Township 8 North, Range 5 West, Section 1) is in the Helena National Forest about 13 miles southwest of Helena, MT. The site (Figure 9) is within the Tenmile Creek drainage above the town of Rimini. Tenmile Creek is used as a source of drinking water for Helena. The site was inventoried in June 1995 and sampled in August 1995. This and other sites in the drainage were summarized in a report on the Upper Missouri River drainage (Metesh and others 1997).

The ore body mined at the Beatrice Mine is a roughly east-west striking, steeply dipping, 4-foot-thick vein of quartz, pyrite, galena, sphalerite, and chalcopyrite. Ruppel (1963) described the workings as including a 450-foot-long adit, a 600-foot crosscut, a 300-foot drift and a 400-foot inclined shaft. The mine operated from 1901 to 1903. No production records are available.

The mine was visited twice during 1995. In early summer, several active discharges visibly affected the water quality of the unnamed tributary. The upper adit had an estimated discharge 20 gal/min that increased the specific conductance of the tributary by a factor of five (conductance upstream of the tributary: 47 µmhos/cm; conductance downstream of the tributary: 243 µmhos/cm). Precipitation of iron-oxyhydroxides was extensive along the entire drainage near the mine. In the uppermost portion of the disturbed area were several open pits, both natural and excavated, with standing or flowing water. All of the mine openings and associated waste-rock dumps are within the same shallow, ephemeral drainage.

In late summer, most of the upper area was dry. There was some standing water in a few of the open pits, but no flowing water. Both adits were dry. In fact, the only flowing water in the area was a small unnamed stream to the south and a spring emerging from the wetlands (Figure 10) well below the workings. Samples collected at that time indicated increased loading of aluminum, copper, and iron to the drainage. The specific

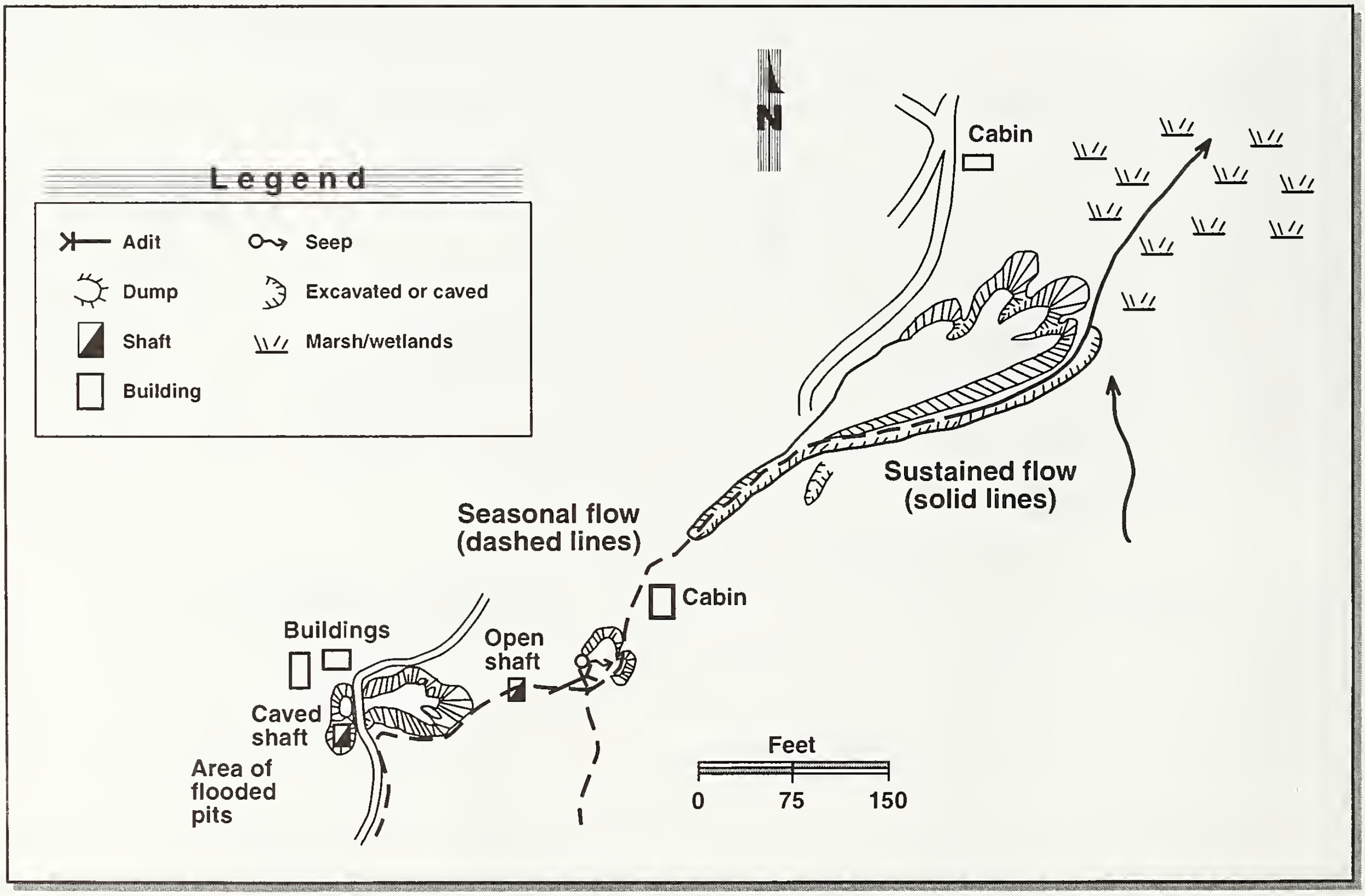


Figure 9—The Beatrice Mine is in the Helena National Forest about 13 miles southwest of Helena, MT. The mine's upper workings discharge water only during the spring and early summer. The water that contributes to the discharge probably comes from the flooded pits above the mine workings.

conductance and pH of the water collected within the wetlands below the site suggested a significant groundwater contribution from the mine workings.

The large seasonal change in the rate of flow from the underground workings (about 20 gal/min in early summer to zero in late summer) indicates that the groundwater recharge zone is close to the mine. The natural depressions and excavations in the area above the mine probably serve as retention and infiltration basins for the workings. If the elevation of the highest discharge point is taken as an approximation of the groundwater surface, the seasonal fluctuation of groundwater levels within the workings is on the order of tens of feet.

Reducing or eliminating adit discharges on this site should probably focus on two aspects. Backfilling and regrading both the natural and excavated area above the mine would probably reduce a significant amount of the recharge to the mine workings. Soil treatment with low-permeability material may further reduce infiltration. Additional removal of waste material from the drainage (Figure 11), along with regrading and soil treatments, would reduce metals loading and infiltration in the vicinity of the lower shaft and adits.

Figure 10—Mine waste was deposited in the wetlands below the Vindicator Mine in southwestern Montana. Waste rock at the site is generating acid mine drainage. Precipitates are deposited in the stream below the mine site.

Figure 11—A disturbed stream channel at the Beatrice Mine site near Helena, MT. The stream is filled with iron hydroxide (precipitated by acid mine drainage).

Summary

Additional information is required for both sites before a comprehensive plan can be completed. In both cases, adit discharge should be monitored throughout the year or, at least during the spring, summer, and fall months. During this same period, infiltration rates and soil permeability should be monitored to identify the rate and direction of the recharge to the workings. The available information suggests that a relatively inexpensive project to control recharge would significantly reduce adit discharge.

References

Elliot, J. E.; Leon, J. S.; Wise, K. K.; and Blaskowski, M. J. 1992. Maps showing locations of mines and prospects in the Butte 1° x 2° quadrangle, western Montana. U.S. Geological Survey Miscellaneous Investigations Series Map I-2050-C. 147 p. Scale 1:250,000.

Hem, J. D.; 1985. Study and interpretation of the chemical characteristics of natural water. U.S. Geological Survey Water Supply Paper 2254, 3rd edition, 263 p.

Loen, J. S.; and Pearson, R.C. 1989. Map showing locations of mines and prospects in the Dillon 1° x 2° quadrangle, Idaho and Montana. U.S. Geological Survey Miscellaneous Investigations Series Map I-1803-C. 85 p. Scale 1:250,000.

Metesh, J. J.; Lonn, J.; Duaime, T. E.; Wintergerst, R. 1994. Abandoned-inactive mines in the Deerlodge National Forest, Volume 1: Basin Creek Drainage. April 1994. Montana Bureau of Mines and Geology Open-file Report 321. 123 p.

Metesh, J. J.; Lonn, J.; Marvin, R. K.; Hargrave, P. A.; Madison, J. P.; Wintergerst, R. 1997. Abandoned-inactive mines in the Helena National Forest, Volume I, Upper Missouri River Drainage. Montana Bureau of Mines and Geology Open-file Report 352, 1997. 195 p.

Pardee, J. T.; Schrader, F. C.1933. Metalliferous deposits in the greater Helena area, Montana. U.S. Geological Survey Bulletin 842. 318 p.

Price, J. G.; Shevenell, L.; Henry, C. D.; Rigby, J. G.; Christensen, L. G.; Lechler, P. J.; Desilets, M. O.; Fields, R.; Driesner, D.; Durbin, B.; Lombardo, W. 1995. Water quality at inactive and abandoned mines in Nevada. Nevada Bureau of Mines and Geology Open-file Report 95-4. 72 p.

Ruppel, E. T. 1963. Geology of the Basin quadrangle, Jefferson, Lewis and Clark, and Powell Counties, Montana. U.S. Geological Survey Bulletin 1151. 121 p.

☆U.S. GOVERNMENT PRINTING OFFICE: 2000-589-317/15050

About the Authors...

Phyllis Hargrave has a bachelor's degree in geology from St. Lawrence University and a master's degree from the Montana College of Mineral Science and Technology. She worked as a geologist in the mineral exploration industry for 15 years before joining the the Montana Bureau of Mines and Geology in 1994. She works primarily for the Bureau's Abandoned and Inactive Mines Program.

John J. Metesh is an associate research hydrogeologist and associate professor for the Montana Bureau of Mines and Geology at Montana Tech. He received a bachelor's degree in geology from Montana State University and a master's degree in geological engineering (hydrogeology) from the Montana College of Mineral Science and Technology. He is certified as a professional geologist by the State of Wisconsin.

Steve Oravetz became Engineering Program Leader in the spring of 1996. He graduated from the University of Washington in Civil Engineering and is now licensed as a Professional Civil Engineer. He began his career on the Wenatchee National Forest in 1980. While there, he worked on Timber Sale Roads preconstruction and construction activities. He also was involved with many recreation facility projects. He became Chief Engineer for the Northeastern Research Station in 1993. He was runner-up for Engineering Manager of the Year in 1994. Steve has worked as a city building inspector and as a consulting Civil Engineer. His hobbies include drawing house plans using computer-aided design (CAD) software, fishing, camping, hunting, and traveling.

Library Card

Metesh, John J., Oravetz, Steve. 2000. Using recharge control to reduce mine adit discharges: a preliminary investigation. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 10 p.

Describes a preliminary investigation to determine whether adit discharges in some abandoned mines in Montana can be reduced or eliminated by reducing groundwater flow into the mine workings (recharge control). The Montana Bureau of Mines and Geology identified 336 sites associated with National Forests or Bureau of Land Management Resource Areas in Montana where one or more adits discharged water at least part of the year. Only 127 of the sites were on Federal land. A total of 141 discharges were sampled. Sixty-three of the discharges exceeded one or more of six water-quality criteria. About 47 of those 63 discharges might be reduced or eliminated with recharge control. Adits that are good candidates for recharge control are those near a drainage divide. Two mines merit further investigation for recharge control: the Vindicator Mine on the Beaverhead-Deerlodge National Forest in southwestern Montana and the Beatrice Mine on the Helena National Forest southwest of Helena, MT. Additional information on both mines will be needed before a comprehensive plan for recharge control can be completed.

Keywords: mined land, passive treatments, remediation

Additional single copies of this document may be ordered from:

USDA Forest Service
Missoula Technology and Development Center
Building 1, Fort Missoula
Missoula, MT 59804-7294
Phone: 406–329–3978
Fax: 406–329–3719
Internet: wo_mtdc_pubs@fs.fed.us

For additional technical information, contact Steve Oravetz at the address above.

Phone: 406–329–1037
Fax: 406–329–3719
Internet: soravetz@fs.fed.us
Lotus Notes: Steve Oravetz/WO/USDAFS

An electronic copy of this document is available on the Forest Service's FSWeb Intranet at:

http://fsweb.mtdc.wo.fs.fed.us